

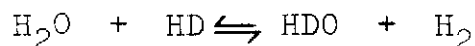
Reactor Boiler and Auxiliaries - Course 133

THE ELECTROLYTIC PROCESS

When water is decomposed electrolytically into hydrogen and oxygen, the deuterium content of the hydrogen produced at the cathode is substantially lower than that of the water remaining in the cell. As electrolysis continues, the water becomes progressively enriched in deuterium. The gas produced in the latter stages of electrolysis is richer in deuterium than the water initially fed; this gas may be burned and the resulting "combustion water" condensed and returned to the cell. The high separation factor ($\gamma = 10$) attainable and the resulting small size of the plant are the main advantages of the electrolysis process when applied to D_2O upgrading.

Mechanism of Operation

Since the equilibrium constant for the reaction



is 3.88 at 25°C and 2.73 at 100°C, it is apparent that the separation factor of 10 observed in electrolysis must be due to some mechanism other than the establishment of equilibrium in this reaction at the cathode surface. One plausible explanation is that the hydrogen ion is discharged more readily at the cathode than the deuterium ion, thus accounting for the tendency of hydrogen to concentrate in the gas. Laboratory findings give some support to this theory. Another possible explanation is the decreased relative mobility of the D^+ and HD^+ ions in the liquid compared to the H^+ ions, so that H^+ ions reach the cathode more quickly than the D^+ or HD^+ ions.

In electrolysis process as applied to heavy water upgrading, a chemical (KOH) is added to the downgraded heavy water to form a current conducting electrolyte, through which a low voltage, high dc current (2000 amps or higher) is passed in an electrolytic cell. As the electrolysis proceeds, ordinary water in the $H_2O - D_2O$ mixture is decomposed more readily than heavy water. The electrolyte remaining behind becomes richer in deuterium content as the process proceeds, until the electrolyte has the desired D_2O concentration. The process is then stopped and the chemical (KOH) extracted to leave reactor grade heavy water.

During the electrolysis, the electrolyte tends to heat up. If the temperature of the electrolyte is not controlled, valuable

D₂O vapour would be carried away from the cell, and thus adversely affect the separation factor.

Description of Electrolytic Cell

The present D₂O electrolytic reconcentration facilities in Canada operate using discarded cells previously used by Consolidated Mining and Smelting, Trail, B.C. in the final stage of their heavy water production plant. Each cell consists of a water-jacketed cylindrical iron body which serves as the cathode (Fig. 1). The anode in each cell is a heavily nickel-plated iron sleeve, insulated from the cover of the cathode, through which it passes, by a gas-tight rubber insulator. The anode is held in a position clear of the cathode by hard rubber studs placed symmetrically around its outer and inner surfaces near the bottom. An inverted iron cylindrical dome is raised from the bottom of the cathode forming an inner cathode which is water-cooled. This reduces the ineffective cell volume and provides a more constant cathode surface area (ie, current density). The piping to each cell is insulated electrically by the installation of sections of rubber hose.

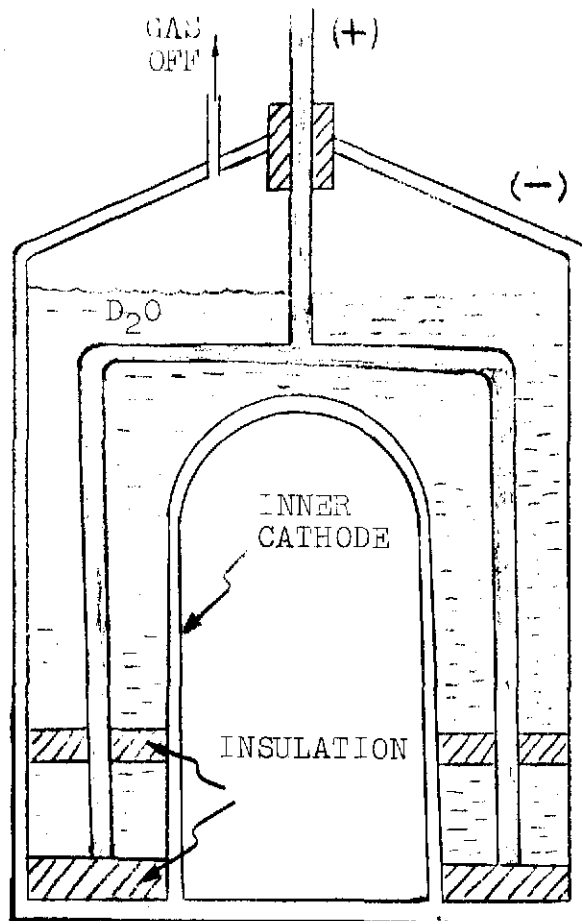


Fig. 1

Method of Operation

Electrolytic reconcentration appears to be best suited to the batch method of operation, although "semi-batch" operation appears feasible. Using this method, a given quantity of downgraded D₂O is upgraded to reactor grade, with possible further feed additions at higher isotopics only when the cell isotopic has reached the new feed isotopic. Fig. 2 shows a simplified flow scheme for a typical upgrading unit. If the unit is connected on-line to the reactor system, cleaning of the feed would be done using the usual

FLOW SHEET - ELECTROLYTIC UPGRADING PLANT

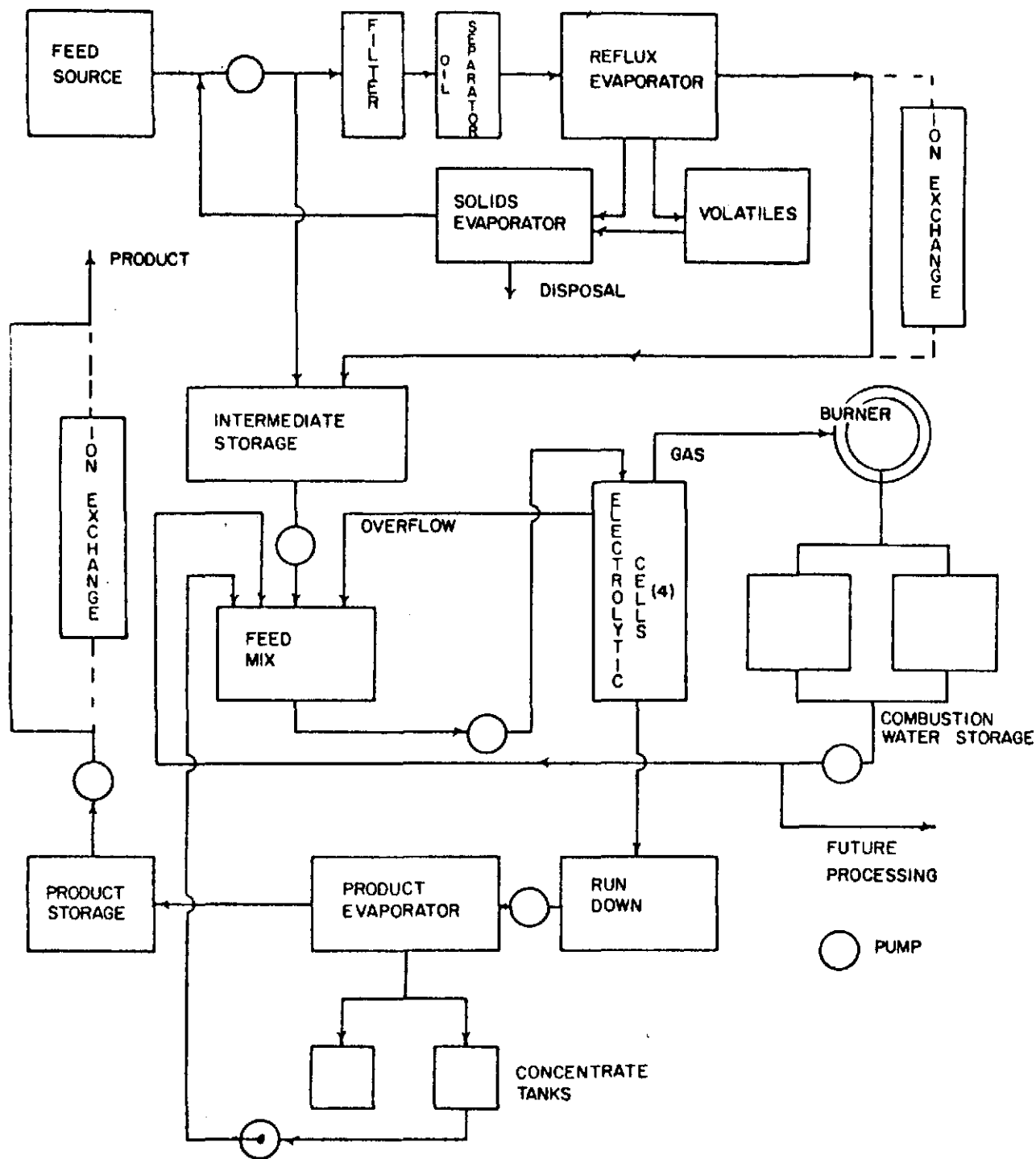
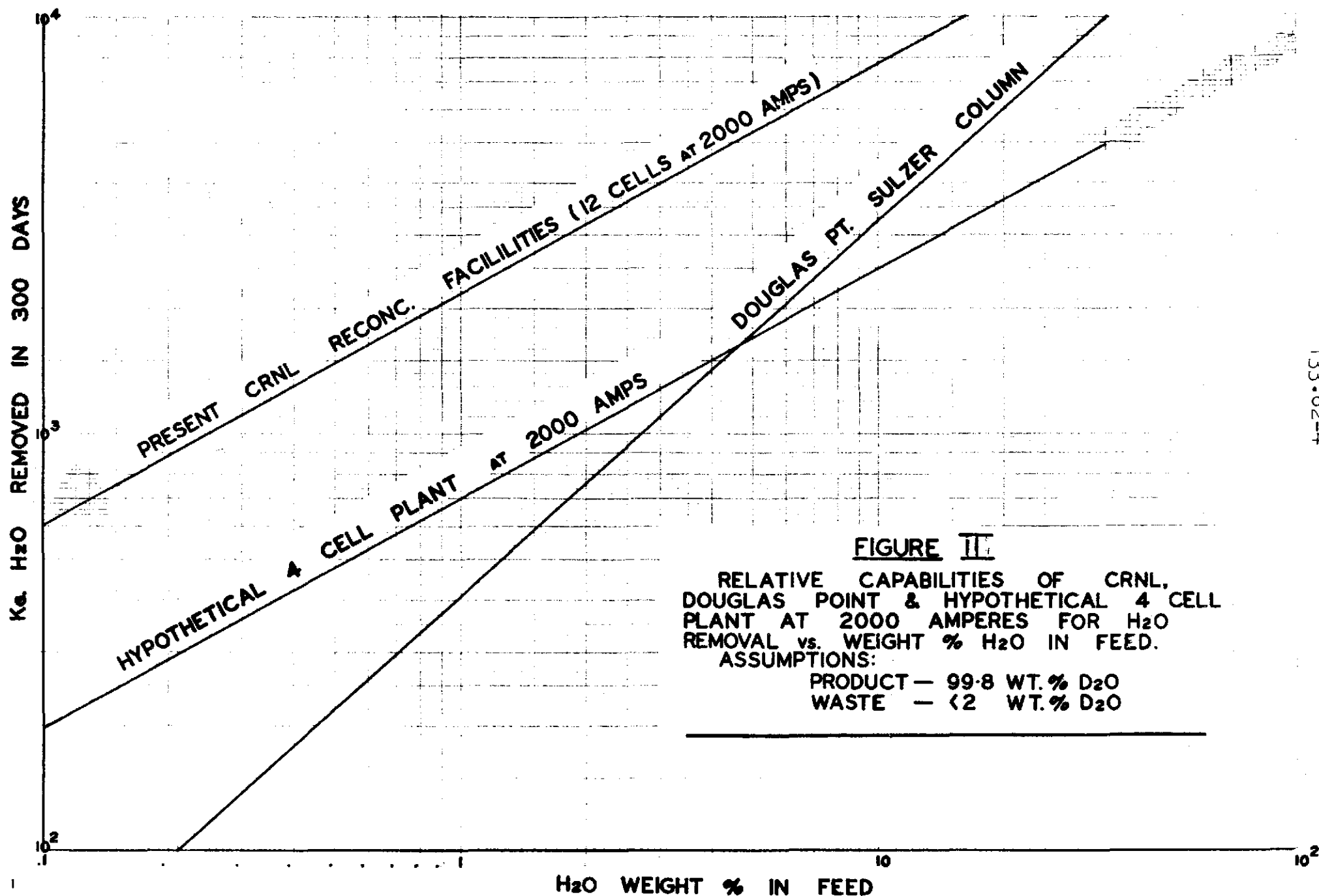


Fig. 2



and CRNL 12-cell unit curves have the same slope, since they both operate at 2000 amps; the H_2O removal capacity of one is three times the other, since it has three times as many cells. Note also that the H_2O removal capacity of the 4-cell plant is greater than that of the Douglas Point column at isotopics above 95 wt. % D_2O (ie, 5% H_2O on graph); alternatively, at lower isotopics, the Douglas Point column has the edge. Thus, the choice of a facility will depend to a large extent on the feed isotopic content either based on past experience, predictions or both.

The electrical consumption and hence power costs are easily estimated for an electrolytic plant. For a 4-cell plant, operating at 2000 amps, utilizing 4 series-connected cells at 2.5 volts per cell and 85% efficiency of rectification, the required power would be

$$P = \frac{4 \times 2000 \times 2.5}{0.85}$$

$$= \underline{\underline{23.5 \text{ kw}}}$$

The operating costs are usually, however, about 90% labour, for an electrolytic reconcentration plant.

ASSIGNMENT

1. What are the main advantages and disadvantages of the electrolytic method of reconcentrating downgraded D_2O ?
2. What are the main pieces of equipment required to utilize the electrolytic method for on-site D_2O upgrading?
3. On what quantity is the production of 'reactor grade' D_2O by electrolysis dependent?
4. How does the H_2O removal ability of a 4-cell electrolytic plant operating at 2000 amps compare with that of the Douglas Point columns? How does it compare if 6 cells are used at the same amperage?

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